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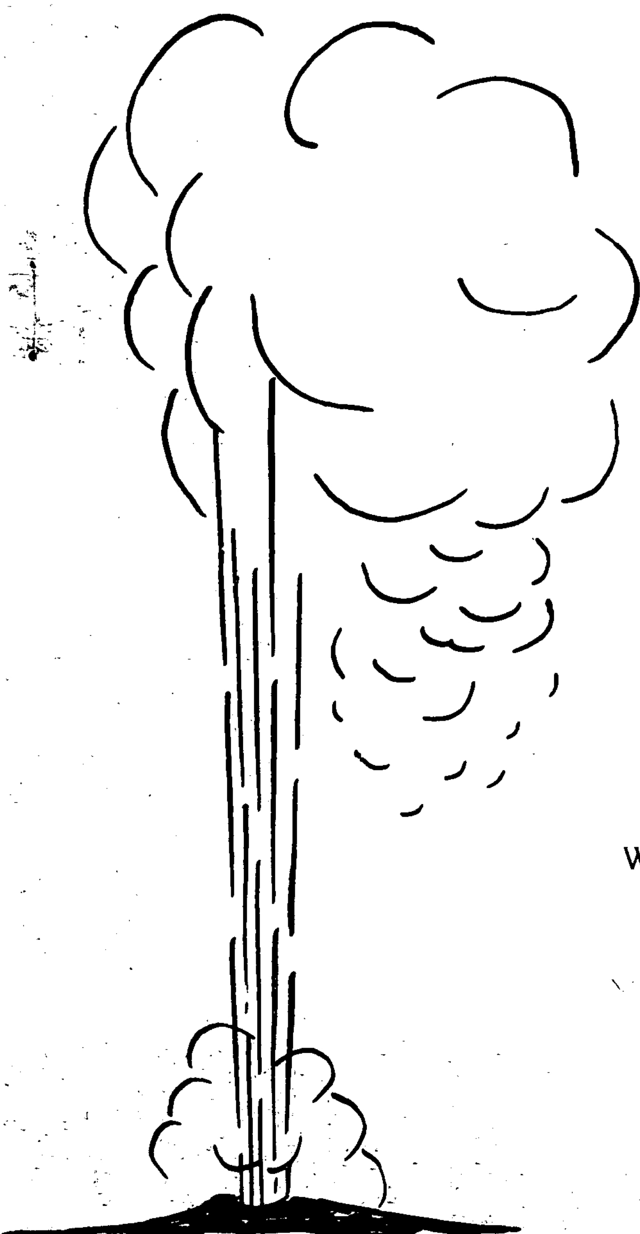

UTAH STATE PRISON SPACE HEATING WITH GEOTHERMAL HEAT

THIRD SEMI-ANNUAL REPORT FOR THE PERIOD JANUARY 1981 — JULY 1981

NOVEMBER 1981

WORK PERFORMED UNDER DOE COOPERATIVE AGREEMENT
NO. DE-FC07-79ET27027

Utah Energy Office
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Salt Lake City, Utah 84114

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

DISCLAIMER

DOE/ET27027-3

Utah State Prison Space Heating With Geothermal Heat Third Semi-Annual Report

January 1981 - July 1981

December

Work performed Under DOE Cooperative Agreement No. DE-FC07-79ET27027

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ABSTRACT

Facing certain cost overruns and lacking information about the long term productivity of the Crystal Hot Springs geothermal resource, costs of construction for the geothermal retrofit, and the method of disposal of geothermal waste water, the Energy Office embarked on a strategy that would enable the project participants to develop accurate cost information on the State Prison Space Heating Program through the completion of Task 5 - Construction. The strategy called for:

1) Completion of the resource assessment to determine whether test well USP/TH-1 could be used as a production well. If well USP/TH-1 was found to have sufficient production capacity, money would not have to be expended on drilling another production well.

2) Evaluation of disposal alternatives and estimation of the cost of each alternative. There was no contingency in the original budget to provide for a reinjection disposal system. Cooperative agreement DE FC07-ET27027 indicated that if a disposal system requiring reinjection was selected for funding that task would be negotiated with DOE and the budget amended accordingly.

3) Completion of the preliminary engineering and design work. Included in this task was a thorough net present value cash flow analysis and an assessment of the technical feasibility of a system retrofit given the production characteristics of well

USP/TH-1. In addition, completion of the preliminary design would provide cost estimates for the construction and commissioning of the minimum security geothermal space heating system.

With this information accurate costs for each task would be available, allowing the Energy Office to develop strategies to optimize the use of money in the existing budget to ensure completion of the program.

Reported herein is a summary of the work towards the completion of these three objectives conducted during the period of January 1981 through June 1981.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

SUMMARY OF TECHNICAL PROGRESS DURING REPORTING PERIOD

The resource monitoring program was designed to enable determination of baseline thermal, hydraulic, and chemical characteristics in the vicinity of Crystal Hot Springs and to provide a history of these characteristics during resource development. To date the thermal monitoring of gradient holes in the vicinity of Crystal Hot Springs has yielded results similar to those of earlier investigations. Development activities that have occured to date have not caused a change in the thermal characteristics of the resource. The limited chemical monitoring conducted early in the program did not yield significant conclusions regarding the chemical characteristics of the Crystal Hot Springs resource except to verify the excellent quality of the geothermal resource. Monthly hydraulic measurements of the Crystal Hot Springs KGRA suggests that Utah Roses', Inc. production has had a noticeable effect upon the resources' hydraulic characteristics.

Due to the uncertainty created by the short preliminary artesian flow test conducted during December 1980, a longer 48 hour program for testing well USP/TH-1 was conducted to provide information to aid in siting and design of a production well and to provide information for preliminary system design activities.

To calculate the noncondensable gas flashpoint, a wellbore pressure profile was measured under artesian flow conditions using a Lynes digital downhole pressure/temperature probe. This allowed accurate determination of the noncondensable gas flashpoint required for production pump selection and downhole setting. Noncondensable gas concentrations at wellhead conditions were found to range from 0.08 to 0.22 weight percent. Using soluability relationships and measured gas concentrations, noncondensable gas flashpoints in the wellbore were calculated to range from 140 feet to 270 feet from the wellhead under hydrostatic wellbore conditions.

Further artesian flow testing was conducted using the Lynes downhole pressure guage. Testing would establish early-time and recovery formation pressure data which would enable determination of important resource information such as near wellbore formation conditions, presence of reservior boundaries, and resource capacity.

The production characteristics of well USP/TH-1 were determined from a controlled 48 hour artesian flow test. Analysis of downhole recovery data indicated a highly permeable reservior of somewhat limited area. Long term production characteristics of well USP/TH-1 were estimated to be limited area. Long term production characteristics of well USP/TH-1 were estimated to be limited due to reservior boundary effects. The well was determined capable of sustaining a flow rate of 100 gpm for 8 months with a drawdown of 275 feet. Production temperature at the wellhead averaged 179°F during the testing.

In May 1981, CH_2M Well was retained to investigate and develop disposal alternatives for the proposed minimum security heating system's spent geothermal water. The options investigated for disposing the water were:

- o undergraound discharge
- o surface discharge
- o sanitary sewer discharge
- o canal discharge
- o river discharge

These options are to be considered individually and in combination from the following stand points; technical feasibility, economic feasibility, institutional acceptability, and environmental acceptability. A final report is anticipated for August 24, 1981.

In addition, CH_2M Hill began work on the preliminary design in June 1981. Work on the preliminary design will proceed on the assumption that 1) some form of surface disposal is the only economically visable option for the project, 2) well productivity will be limited to 100 gpm average for an 8 month season.

PROJECT BACKGROUND

In July, 1978 the Utah Energy Office, on behalf of the State of Utah, submitted a successful proposal to the Department of Energy (DOE) in response to a Program Opportunity Notice (PON) for Direct Utilization of Geothermal Energy Resources.

The Utah Energy Office PON proposal proposed to develop the Crystal Hot Springs geothermal resource located on private property adjacent to the Utah State Prison at the southern end of the Salt Lake Valley. The objective of the PON was to demonstrate the economic and technical feasibility of providing sufficient geothermal water for use in a variety of direct applications at suitable sites within the Utah State Prison complex. A geothermal well, heat exchange system, and injection disposal well were proposed to form the initial demonstration of providing geothermal water for space heating and domestic water heating for the minimum security facility at the Prison.

Consisting of dorms, offices, a gymnasium, and a cafeteria, the 72,000 square foot minimum security facility was considered a good candidate for retrofit to geothermal energy for three reasons.

1. Due to its size and function, the facility consumed a large portion of the energy used at the Prison,

2. The minimum security facility's location as the nearest major prison building to the Crystal Hot Springs resource; a distance of only 400 meters, and

3. The existing building's space heating system was a hot water system and was considered to be a relatively easy retrofit for a geothermal heating system.

The initial demonstration of providing the minimum security facility with space and hot water heating was intended to form the nucleus of a system which potentially could be expanded to provide the bulk of the heating requirements for the entire Prison.

In order to meet the objectives of the PON proposal, the Utah Energy Office programmed the project into three phases consisting of:

<u>Phase I - Resource Assessment</u>

- Additional geophysical reconnaissance comprised of aeromagnetic and gravity surveys of the Crystal Hot Springs resource area.

- Resource monitoring program to establish baseline thermal, hydraulic, and chemical characteristics of the Crystal Hot Springs resource area.

- Selection of a drilling site on Prison property for a deep test well.

- Short term artesian flow testing program to assist in fixing a production well design and to provide information needed for completion of a preliminary heating system design.

Phase II - Resource Development

- Selection of a site on Prison property for drilling a production well.

- Detailed evaluation of well and reservoir characteristics.

- Investigation of disposal alternatives.

- Preliminary system design and economic and technical feasibilty assessment.

Phase III - Construction and Inspection of Demonstration

- Final system design.

- System construction.

- Commissioning and initiation of monitoring and performance verification program.

Work on the project was to begin in March, 1979, with the writing of the environmental report and culminate with the startup of the heating system in September of 1982.

The total estimated cost for the project was $637,326 with a cost share arrangement assigning $458,704 to DOE and $178,622 to the State of Utah.

PROJECT DESCRIPTION

Resource

Development is focused on the Crystal Hot Springs geothermal resource, the surface expression of which is located on private property adjacent to Prison property.

The Crystal Hot Springs geothermal system is a deep convective system located at the eastern margin of the Basin and Range physiographic province. The thermal springs are located north of an east-northeast trending horst that is perpendicular to the structural trend of Wasatch Front grabens. The horst, known as the Traverse Range, consists of highly fractured mid-Paleozoic quartzites and tertiary volcanics. Meteoric water enters the system in the adjacent ranges, circulates to depths of 3 Km, and is heated. The thermal fluids return to the surface along steeply dipping range front faults that bound the northern flank of the range. The thermal springs issue between two such faults that are buried beneath Tertiary and Quatenary age valley fill deposits. Highly fractured quartzite beneath the valley fill act as a near-surface reservoir for the thermal water that is being targeted for development.

The surface expression is defined by several hot water spring discharges contained within a 70 acre area. At the center of the Crystal Hot springs resource area springs issue to the surface through alluvium that is approximately 80 feet thick.

The maximum measured temperature at Crystal Hot Springs is 98° C, recorded in the bottom of the 410 foot Utah Roses well. The chemical quality of the thermal waters are excellent. The total dissolved solids content is between 1,500 - 1,700 ppm.

System Design

In the minimum security facility's existing system, heat from steam supplied by the natural gas fired central boiler plant, is exchanged onto fresh water which is circulated through the building. This system will be modified by the addition of geothermal water/fresh water heat exchangers in series with steam/water units for both space and culinary water heating. Apart from supplementary pumping capacity, the rest of the system will be left essentially in tact.

To produce the necessary flows from USP/TH-1, the well will be pumped. A 50 hp vertical turbine pump, set at approximately 500 feet, capable of producing flows up to 288 gpm, is proposed. The pump discharge will connect to a 6-inch diameter epoxy-lined insulated asbestos-cement transmission pipeline, buried at a safe depth. The transmission pipeline will be routed as directly as possible to the two mechanical rooms in the minimum security facility.

Heat Exchangers

Located either within these mechanical rooms or just outside in their areaways, plate-type heat exchangers will transfer heat from the 175° F

RESOURCE MONITORING AND RESERVOIR TESTING PROGRAM

RESOURCE MONITORING PROGRAM

As a part of the resource assessment portion of the Utah State Prison Geothermal Project, a program for periodic monitoring of the Crystal Hot Springs resource was formulated. The program was designed to enable determination of baseline thermal, hydraulic, and chemical characteristics in the vicinity of Crystal Hot Springs prior to production and also to provide a history of these characteristics during resource development. A program such as this was necessary to aid in evolving a strategy for effectively utilizing the resource.

Resource monitoring conducted to date has consisted of periodically making thermal and hydraulic measurements and analyzing the water chemistry of the wells and springs in the area. Presented in Figure 1 is a map of the current configuration of the Crystal Hot Springs region. The locations of water wells, temperature gradient holes, and surface waters (formed from spring discharges) included within the monitoring program are shown on the map.

The monitoring program as originally formulated is presented in the following section of the report. Modifications to the originally outlined program, dictated by project budget constraints, are described in the discussion of Results to Date and the Monitoring Program.

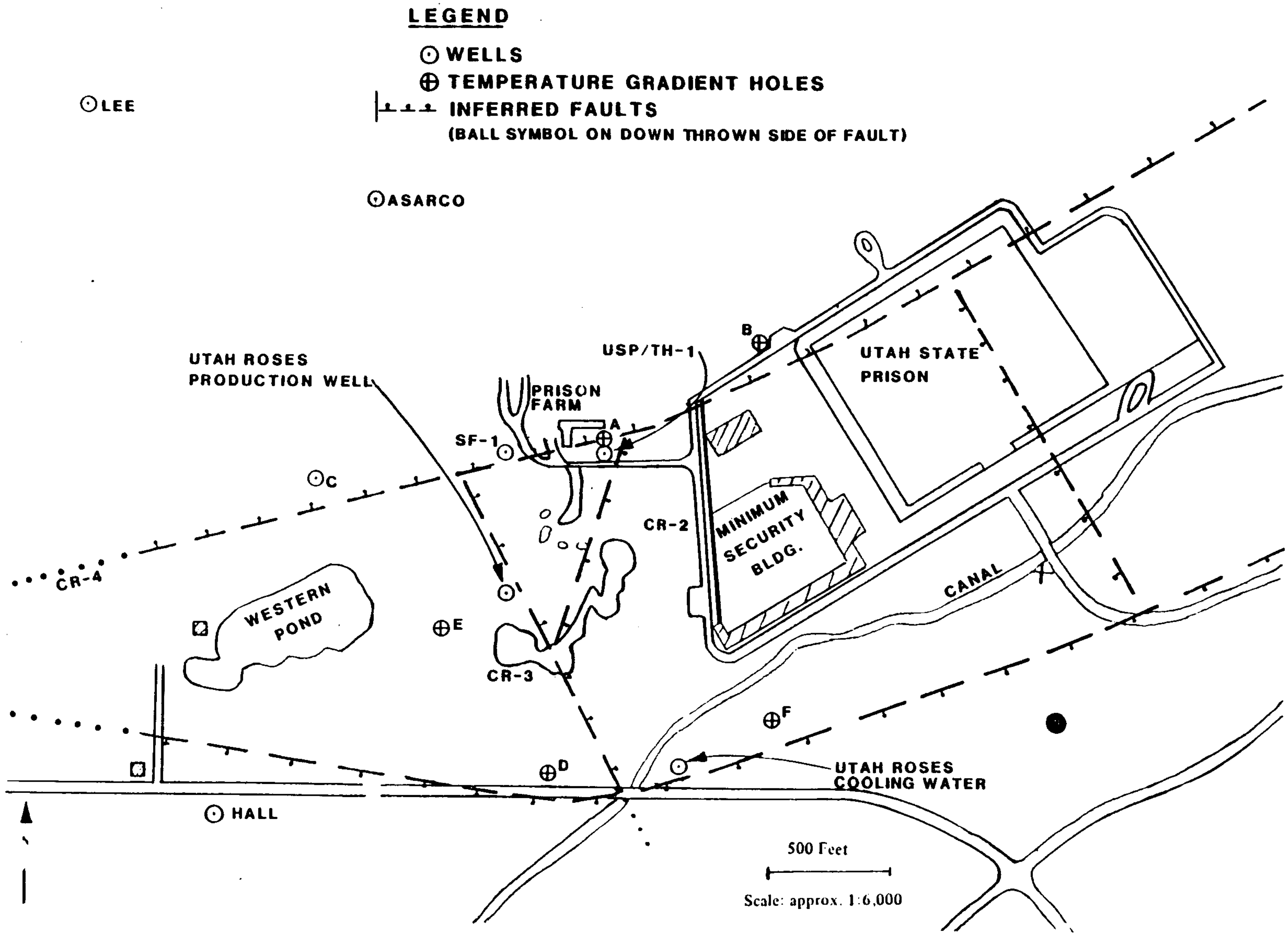


FIGURE 1

MONITORING LOCATIONS-CRYSTAL HOT SPRINGS AREA

Thermal Monitoring

Temperature measurements were made in the following wells:

Gradient Holes B, C, D, E, and F

State Forestry Well SF-1

Test Well USP/TH-1

ASARCO

Lee

Temperatures were measured from the surface to total depth at 10 foot intervals using a downhole temperature measurement probe. Wells SF-1 and USP/TH-1 flow artesian. Static and flowing temperature logs of these wells were obtained. Well temperature measurements were made at four month intervals. In addition to the outlined well temperature measurements, the discharge temperature of the eastern springs (CR-1, CR-2, and CR-3) were measured monthly.

In the originally outlined program, a temperature survey of the western pond (and associated submerged springs) was to have been made on a yearly basis. The discharge temperature of four shallow culinary water supply wells were also to have been measured at one year intervals. These measurements were eliminated from the program to decrease program costs.

Hydraulic Monitoring

Hydraulic measurements were made on a monthly basis in the following:

Gradient Holes A, B, D, E, and F

State Forestry Well SF-1

Test Well USP/TH-1

ASARCO

Lee

Gradient Hole A, State Forestry Well SF-1, and Test Well USP/TH-1 flow artesian. Wellhead pressures in these wells were measured with a pressure gauge or manometer of appropriate range following shut-in for a period of time sufficient to ensure that equilibrium conditions exist. The remaining gradient holes and wells have static water levels which are below the surface of the ground. Water levels in these wells were measured with an electrical conductivity probe.

The discharge rates from the eastern springs were measured monthly. Two of the eastern cumulative discharges (SR-2 and SR3) were measured using Parshal Metering Flumes. It was not possible to install a metering flume to measure discharge of CR-1 due to the physical configuration of the spring discharge.

Items originally outlined for monitoring but later dropped from the program include measurement of static water levels in domestic wells Lear, Peterson, Fitzgerald, and Prison on a semi-yearly basis and measurement of the discharge from the western pond on a monthly basis.

Chemical Monitoring

The entire chemical portion of the monitoring program was deleted shortly after the first series of field samples had been obtained and field measurements had been made. The program as originally outlined was as follows:

Samples for chemical analysis were to have been obtained on a periodic basis from the following:

Thermal Wells

State Forestry Well SF-1
Test Well USP/TH-1
Gradient Hole A

Water Wells

Prison
Peterson
Lear
Fitzgerald
ASARCO
LEE

Springs and Ponds

Eastern Springs (CR-1, CR-2 and CR-3)

Western Pond (CR-4)

The thermal wells were to have been sampled every six months. Water wells, springs, and ponds were to have been sampled on a yearly basis.

Samples from the artesian thermal wells were to be obtained at the wellheads from the discharge flows. Prior to sampling, the wells were to be produced for a period of time sufficient to provide equilibrium temperatures at the wellhead. Samples from domestic wells having static water levels below the surface (Peterson, Lear, and Fitzgerald) were to be obtained at the points of discharge from the well pumps. Currently unused water wells having static water levels below the surface (ASARCO and Lee) were to have been sampled via use of a submersible point sampler.

The flow from the eastern series of springs currently discharges into three drainage ditches. Samples were to be obtained from those ditches as close to the point of spring discharge as possible. The springs associated with the western pond were to be sampled via use of a submersible point sampler.

Results of the thermal monitoring program to date are summarized in Figures 2 to 5 and in Table I. Results from hydraulic monitoring are presented in Figures 6 to 9. The results of chemical monitoring are outlined in Tables II - IV.

Findings and Summary of Resource Monitoring Program

Thermal monitoring of the gradient holes in the vicinity of Crystal Hot Springs conducted to date has yielded results very similar to those of an earlier investigation by the Utah Geological Survey (Reference 2).

TABLE I

TEMPERATURE DATA OF - HOT SPRINGS DISCHARGE

	Monitoring Date				
Spring No.	10/1/80	10/21/80	10/24/80	10/28/80	2/20/81
CR-1	135	136	131	--	192
CR-2	113	97	93	97	91
CR-3	85	75	68	64	50

Briefly summarizing these results, temperatures in excess of 160 degrees F were present in portions of radient Holes C, D, and E (indicating that these holes penetrate the producing formation). Water wells ASARCO and Lee and Gradient Holes B and F exhibit anomalous thermal characteristics (gradients on the order of 180 degrees F per 1,000 feet) suggesting that these wells are influenced by, but are not completed, within the producing formation. The consistency of the results obtained during the current project and during the previous investigation indicate that the development activities that have occurred to date have not caused a change in the thermal characteristics of the resource.

Monitoring of the test wells drilling during the project indicate that the producing formation in the vicinity of the prison is essentially isothermal from a depth of 300 feet to 700 feet at 175 degrees F. A temperature inversion was observed in Well USP/TH-1 below a depth of 700 feet.

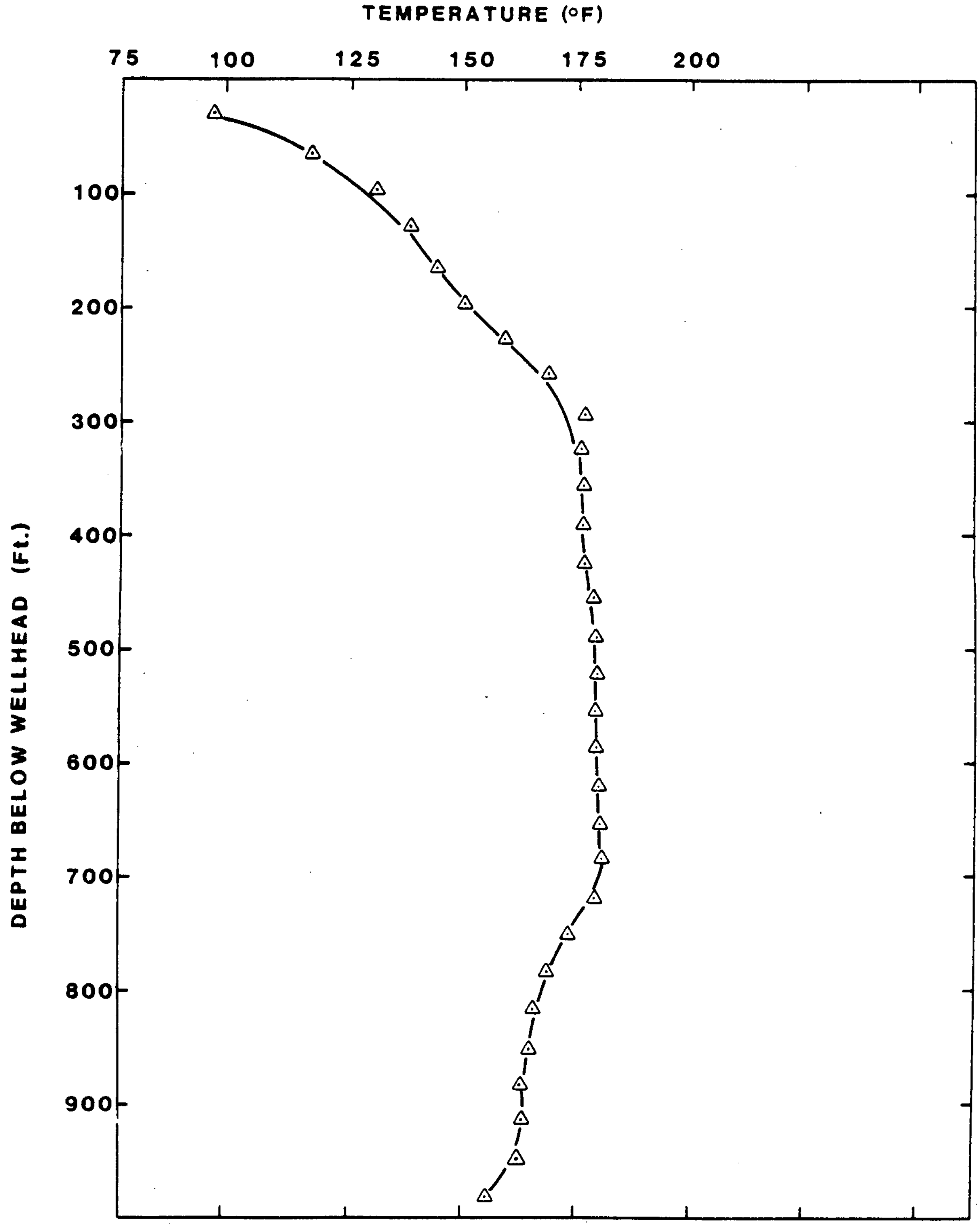


FIGURE 2

STATIC TEMPERATURE PROFILE FOR WELL USP/TH-1 (DEC. 1980)

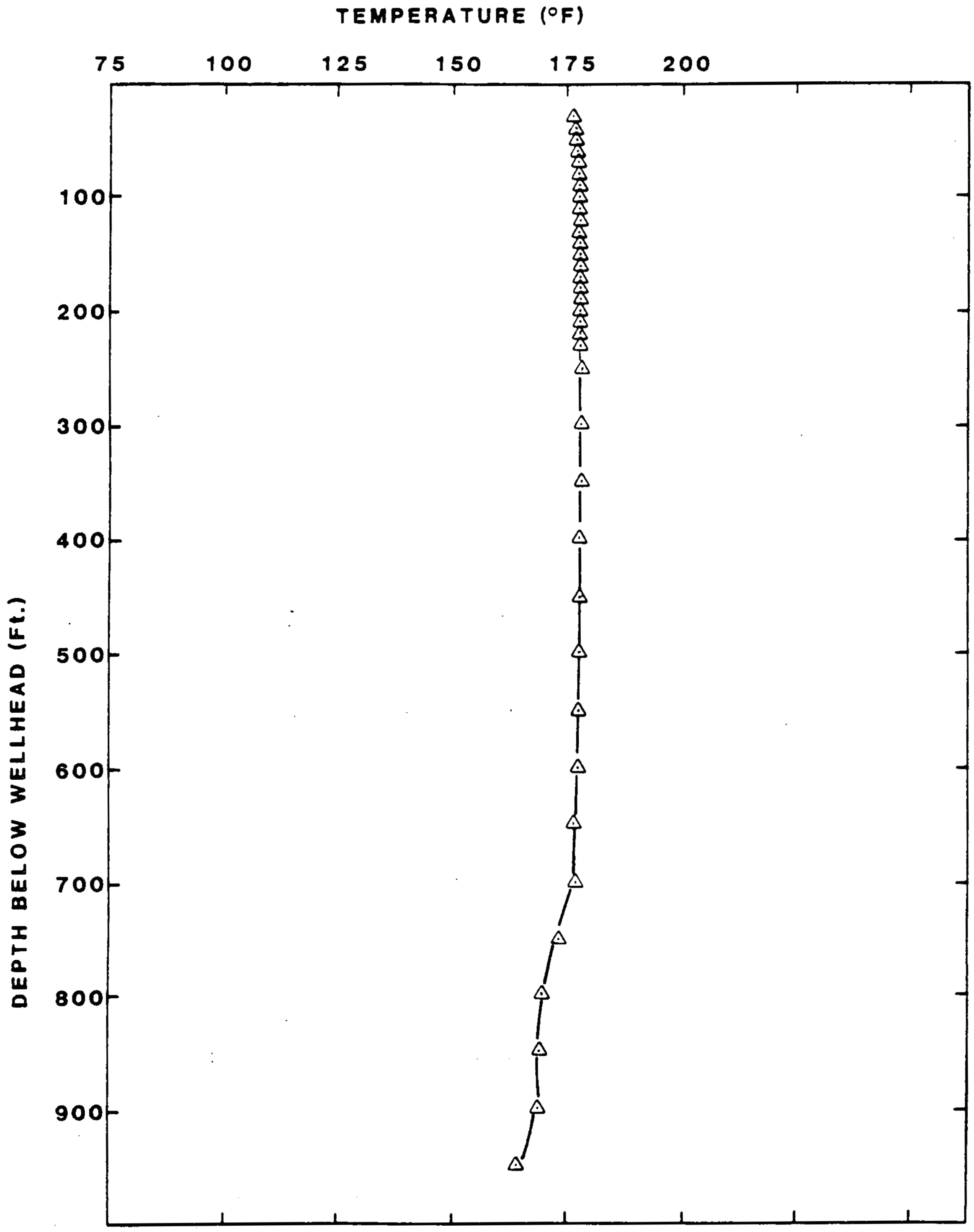


FIGURE 3

FLOWING WELL TEMPERATURE PROFILE
FOR WELL USP/TH-1 (FEB. 1981)

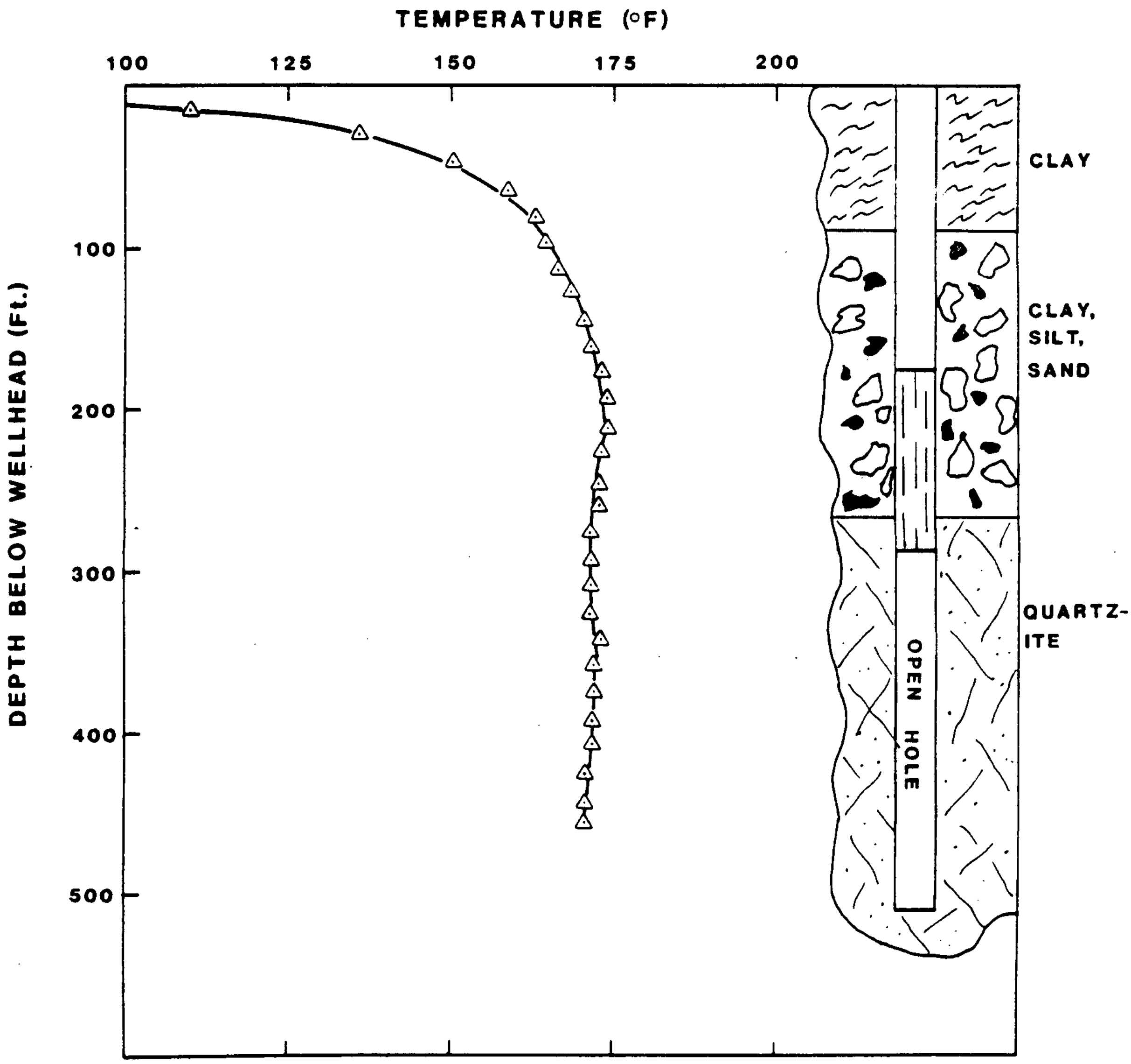


FIGURE 4
STATIC TEMPERATURE PROFILE
FOR WELL SF-1 (DEC. 1980)

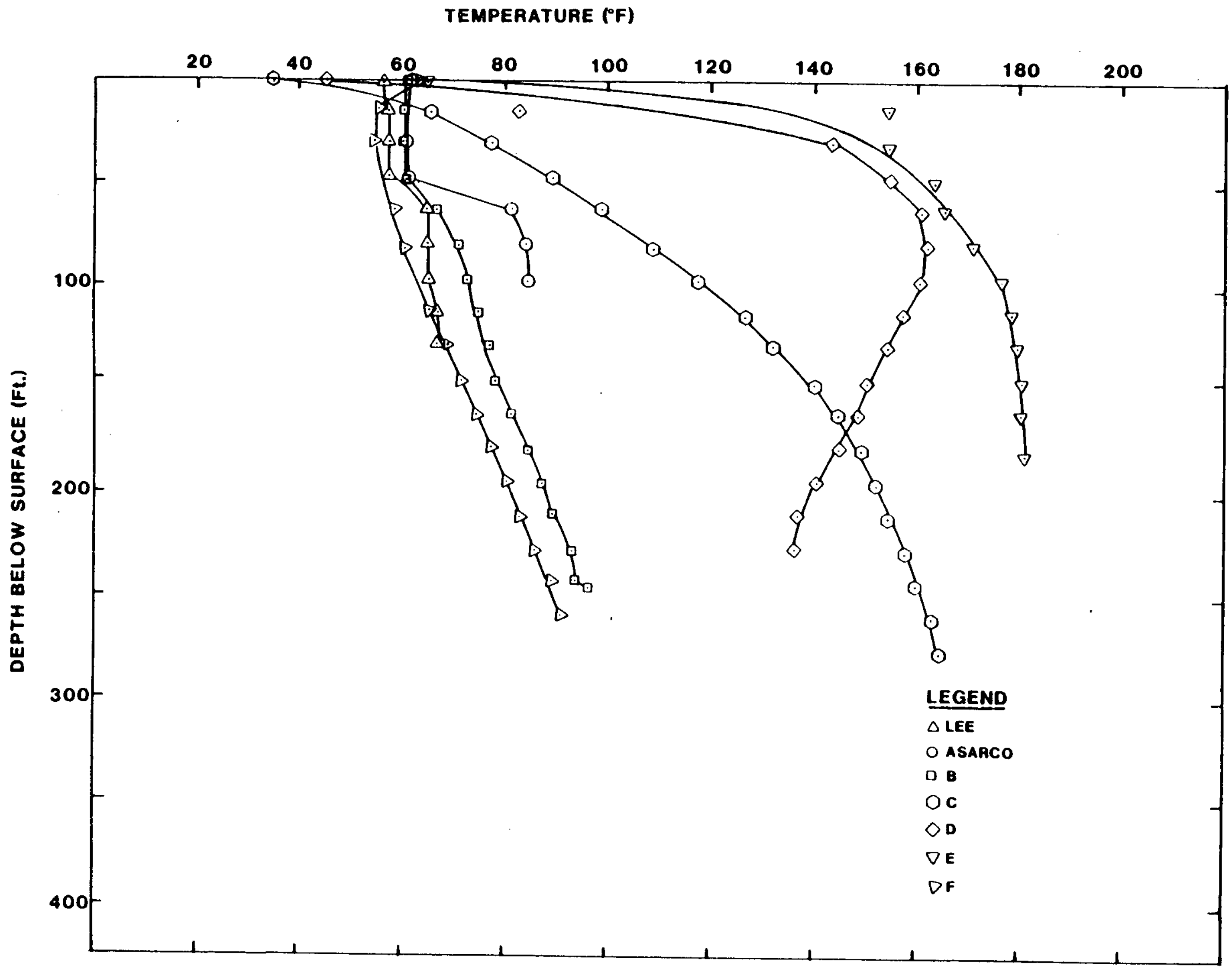


FIGURE 5

TEMPERATURE PROFILES FOR GRADIENT HOLES AND CULINARY WELLS (NOV.-DEC. 1980)

At this time it has not been determined whether or not the observed temperature profile in USP/TH-1 is indicative of resource characteristics. The inversion could be a resource thermal transient caused by a cold water quenching operation conducted during drilling. The increase in bottom hole temperature versus time in the well (December, 1980 data in Figure 10 and February, 1981 data in Figure 11) indicate that the formation at depth has not reached thermal equilibrium following the quenching operation.

Results of hydraulic monitoring activities for gradient Holes B and F and water wells Lee and ASARCO, indicate these wells that were not completed within the producing formation, do not appear to have been influenced by production activities conducted to date at the Crystal Hot Springs. Although completed within the quartzite formation, Gradient Hole E was found to have highly variant water levels with no discernible trends over the monitoring period. The behavior of Gradient Hole E is perhaps indicative that the well is not in good hydraulic connection with the quartzite formation.

Utah Roses' production appears to have had a noticeable effect upon the Crystal Hot Springs' hydraulic characteristics. The significant drop in wellhead pressures of wells SF-1 and USP/TH-1 (Figure 9), static water level in Gradient Hole D (Figure 6), and flow rate from Springs CR-2 and CR-3 (Figure 8) during October of 1980 coincide with the initiation of Utah Roses' production.

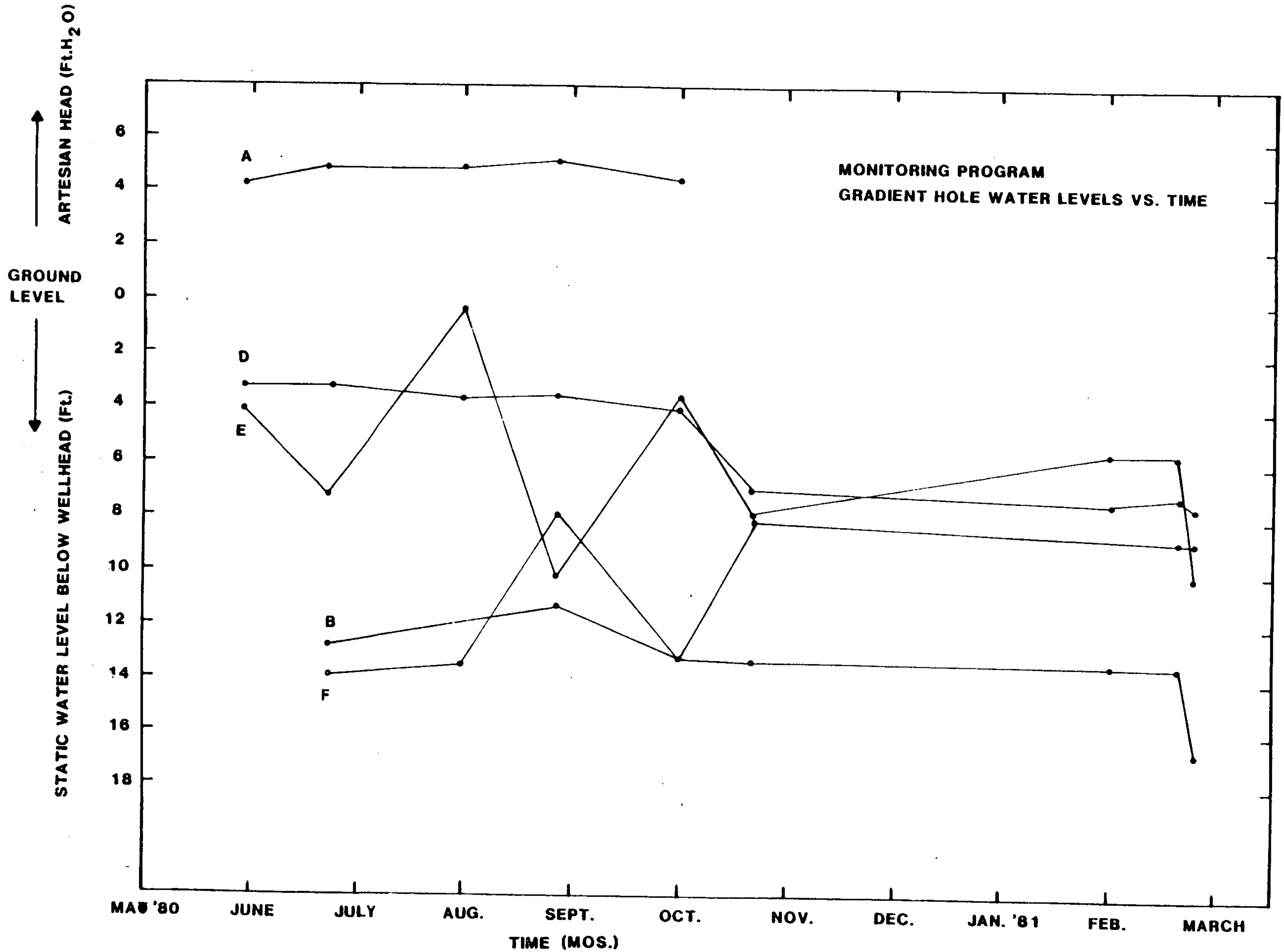


FIGURE 6

MONITORING PROGRAM - GRADIENT HOLE WATER LEVELS VS. TIME

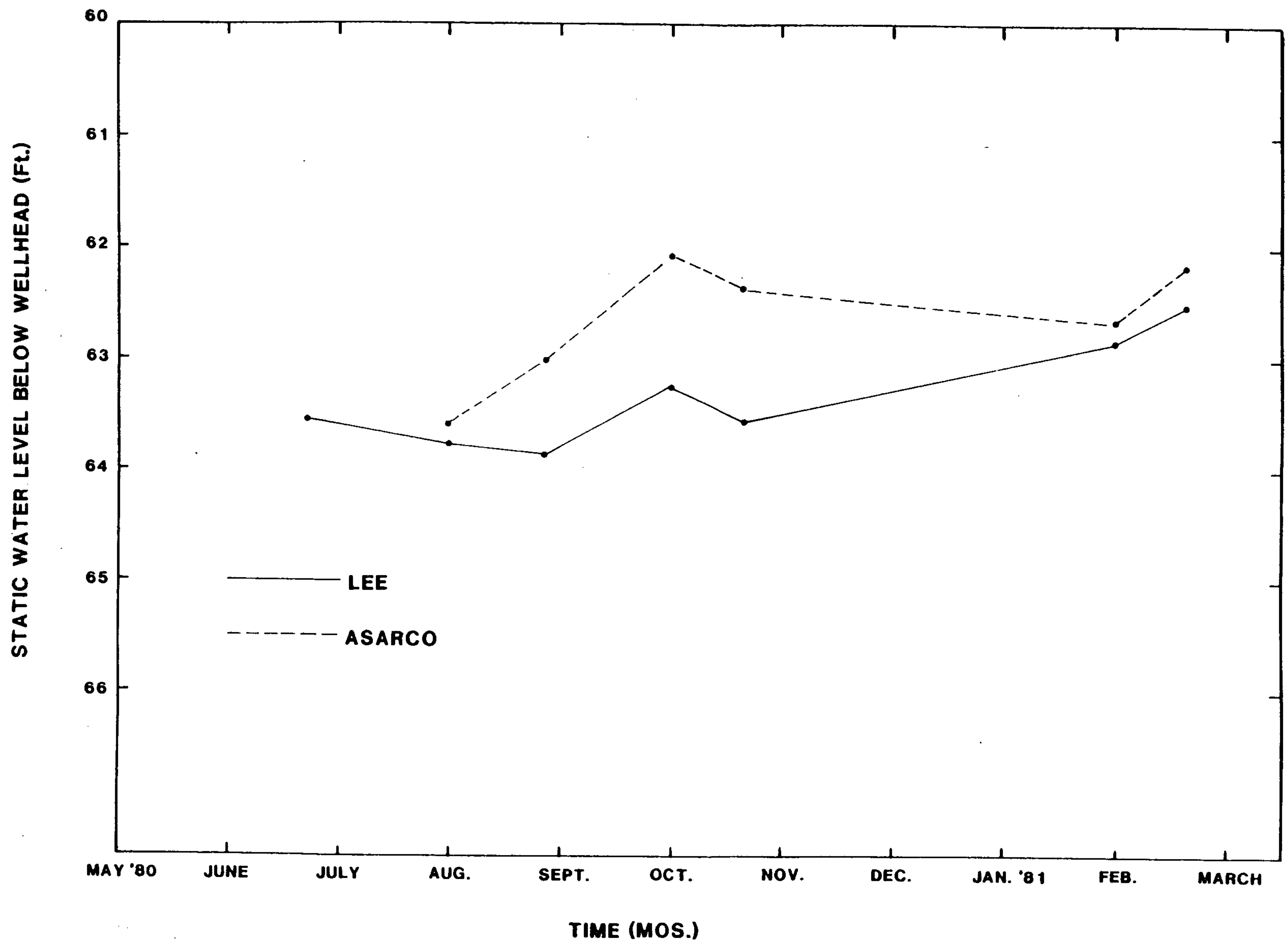


FIGURE 7

STATIC WATER LEVELS IN WELLS LEE AND ASARCO

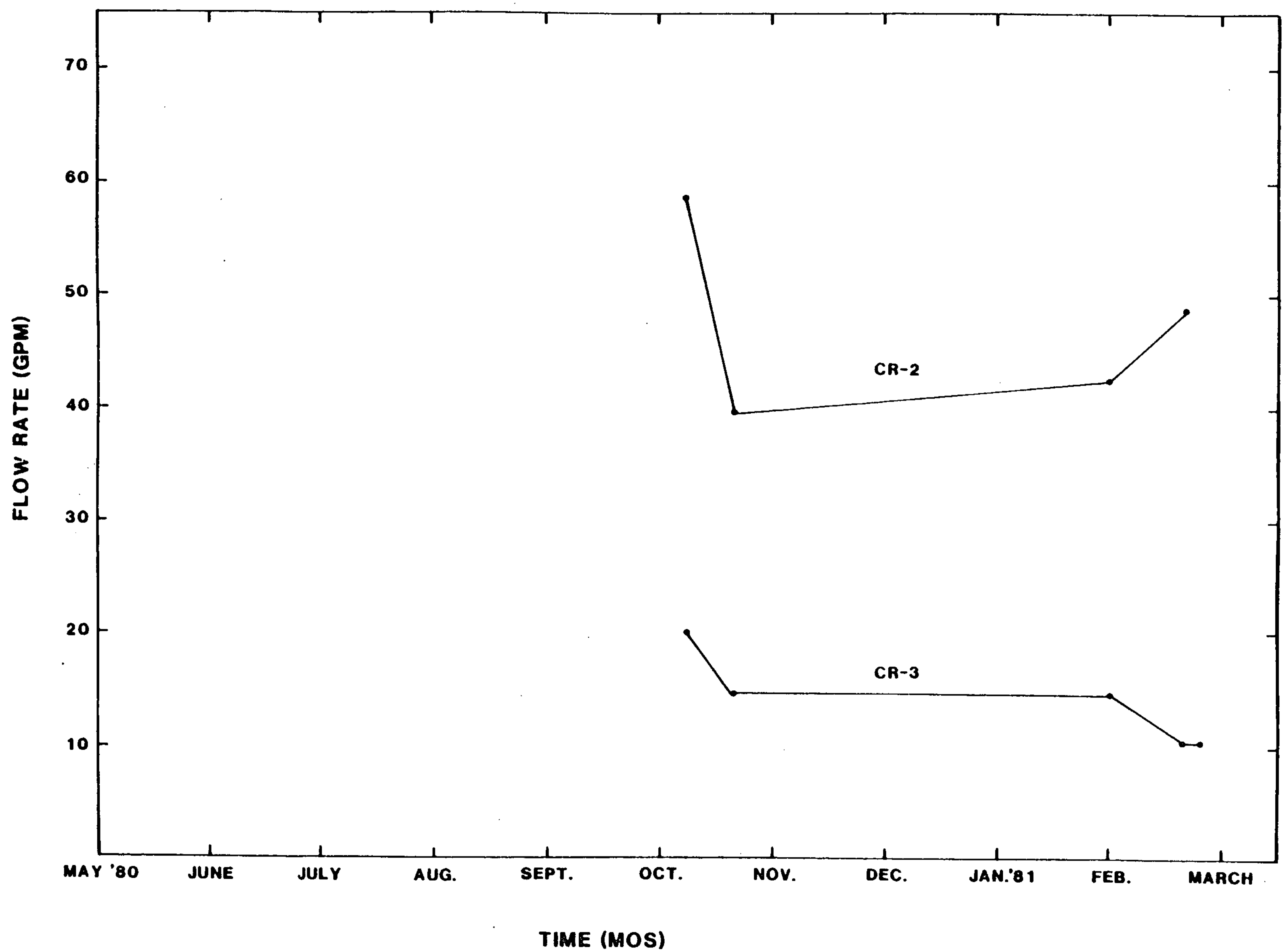


FIGURE 8

THERMAL SPRINGS CR-2 AND CR-3 FLOW RATES

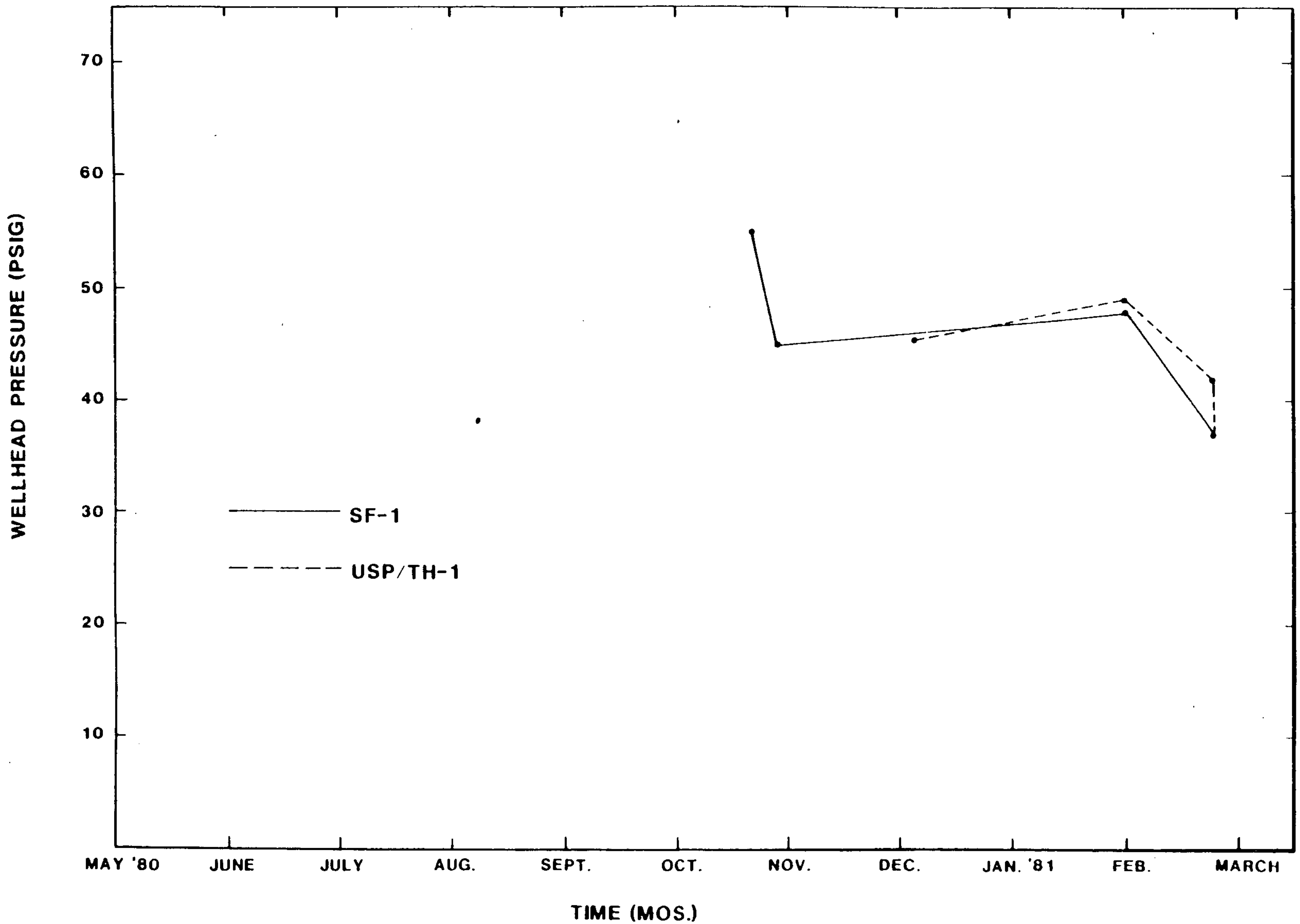


FIGURE 9

STATIC WELLHEAD PRESSURES IN WELLS SF-1 AND USP/TH-1

The chemical quality of the geothermal water of Crystal Hot Springs is excellent by comparison to other low temperature geothermal waters along the Wasatch Front. The total dissolved solids content has been used to rank the general water quaility of Wasatch Front springs as presented in Table II.

TABLE II

WASATCH FRONT THERMAL SPRINGS

Spring	Approximate TDS (mg/1)*	Maximum Reported Temperature
Crystal	1,500	187°F
Saratoga	1,500	111°F
Udy	7,900	121°F
Wasatch	8,600	108°F
Beck	13,700	132°F
Utah	29,200	144°F
Crystal (Madsen)	42,900	135°F

*From Mundorff (1970)

The factors contributing to the anomolously good quality of the thermal waters at Crystal Hot Springs are not fully understood, however, a number of factors could possibly contribute to the observed water chemistry. First, the water recharging the system is know melt and low in total dissolved solids. Second, the water may move rapidly through the system thereby decreasing the time available for the dissolution of soluble components along the flow path. Third, the material through which the water flows is not readily soluble. Fourth, the thermal water has not been contaminated with nonthermal brines.

The preliminary chemical monitoring conducted early within the program was not sufficient to yield any significant conclusions regarding the chemical characteristics of the Crystal Hot Springs Resource. (Table IV) However, the State Department of Health took samples of water from USP/TH-1 and performed a water qualify analysis on the geothermal fluid. CH2M Hill under subcontract to the Utah Energy Office subsequently compiled additonal chemical data for the resource under Task 4 Investigation of disposal alternatives.

An analysis of the geothermal water from USP/TH-1 is presented in Table V. To help illustrate the high quality of the geothermal water, a comparison to drinking water standards is included. The parameters were determined by the State Health Department laboratory on a sample taken in February, 1981.

A gas sample from USP/TH-1 was not analyzed, but the noncondensable gas is believed to be mostly CO_2. Noncondensable gas concentrations at wellhead conditions comprise from 0.08 to 0.22 percent by weight of the geothermal fluid. A complete noncondensable gas analysis is available for the primary production well supplying Utah Roses' greenhouse complex with hot water. Data is also avalable for this well. This data summarized in Table VI. Based on this data, it can be concluded that noncondensable gas emissions at Crystal Hot Springs will not represent a problem.

TABLE III

CHEMICAL MONITORING DATA

Date	Location	pH	Conductivity MMHO/cm	Sampling Temp.(°C)	TDS
10/1/80	Gradient Hole A	5.75	--	45	--
10/24/80	Gradient Hole A	5.49	2.6×10^3	32	--
10/24/80	Spring CR-1	5.79	3.4×10^3	55	--
10/24/80	Spring CR-2	6.44	2.9×10^3	34	--
10/24/80	Spring CR-3	6.75	2.6×10^3	20	--
10/28/80	Well SF-1	6.5	4.3×10^3	77	--
11/6/80	Spring CR-4	7.03	2.5×10^3	25	2009
11/6/80	Western Pond	6.77	2.3×10^3	23	1336

TABLE IV

WATER ANALYSIS

UTAH STATE PRISON GEOTHERMAL WELL (USP/TH-1)

	Units	Geothermal Well[a]	Comparison to Drinking Water Standards: Primary Drinking Water Standards Maximum Levels[b]	Comparison to Drinking Water Standards: Secondary Drinking Water Standards Recommended Limits[b]
Temperature	°F	179	2,000[c]	
TDS	ppm	1,754.		
Sp. cond.	umhos/cm	3,130.		
pH		7.0		6.5 - 8.5
$NO_2 + NO_3$ as N	mg/l	0.07		
T.K.N.[d]	mg/l	0.07		
T.O.C.[e]	mg/l	1.0		
C.O.D.	mg/l	15.		
Phenolic	mg/l	0.003		
--------CATIONS--------				
Ammonia as N(ionized)	mg/l	0.7		
Boron	ug/l	1,555.0		
Calcium	mg/l	154.		
Chromiun, Hex.as Cr	ug/l	5.0		
Magnesium	mg/l	30.		
Potassium	mg/l	78.		
Sodium	mg/l	495.0		
	(Total Cations	757)		
--------ANIONS--------				
Bicarbonate	mg/l	416.		
Carbon Dioxide	mg/l	67.		
Carbonate	mg/l	0.		
Chloride	mg/l	750.		250
CO_3 Solids	mg/l	205.		
Flüoride	mg/l	2.05	1.6 - 2.0[f]	
Hydroxide	mg/l	0.00		
Nitrate as N	mg/l	0.07	10.	
Nitrate as N	mg/l	0.05		
Phosphorus,Ortho as P	mg/l	0.02		
Silica, Dissolved as SiO_2	mg/l	40.		
Sulfate	mg/l	71.	500	
	(Total Anions	1,066)		
	(Grand Total	1,823)		

TABLE IV -- CONTINUED

	Units	Geothermal Well[a]	Comparison to Drinking Water Standards: Primary Drinking Water Standards Maximum Levels[b]	Secondary Drinking Water Standards Recommended Limits[b]
----------TOTAL METALS ANALYSIS---------				
Arsenic	ug/l	200.0	50.	
Barium	mg/l	0.41	1.	
Cadmium	ug/l	1.	10.	
Chromium	ug/l	5.	50.	
Copper	ug/l	10.		1,000
Iron	mg/l	0.63		0.3
Lead	ug/l	7.	50.	
Manganese	ug/l	560.		50
Mercury	ug/l	0.1	2.	
Nickel	ug/l	10.		
Selenium	ug/l	1.	10.	
Silver	ug/l	2.	50.	5,000
Zinc	ug/l	5.		
----------OTHER----------				
Total Phosphorus	mg/l	0.05		
Total Alk.as $CaCO_3$	mg/l	341.		
Total Hdns.as $CaCO_3$	mg/l	508.0		
Turbidity,as NTU		8.5	5.0	
----------RADIOLOGICS----------				
Alpha, gross	pCi/l	183	15 (combined)	
226 Radium	pCi/l	20		

[a]Utah State Department of Health Environmental Health Laboratory, February 27, 1981. Analysis covers only those constituents normally tested for by the Department.

[b]Utah Safe Drinking Water Committee.

[c]If TDS is greater than 1,000 mg/l, the supplier shall show to the Committee that no better water is available.

[d]Total Kjeldahl Nitrogen.

[e]Total Organic Carbon.

[f]Depends on ambient air temperature.

[g]Because of the level of TDS, the accuracy of the radiologics may have been affected.

NOTE: denotes constituent level was below detectable limit of the approved method.

WELL USP/TH-1 TESTING PROGRAM

A program for testing of Well USP/TH-1 was conducted to provide information required to aid in siting and design of the production well to be drilled during the project and to provide information required for preliminary system design activities. The specific goals of the testing program were as follows:

1. To determine the point within the wellbore at which noncondensable gases dissolved within the production fluid begin to evolve as free gas.
2. To determine the flow/pressure drawdown characteristics of the well and the production fluid temperature versus time.
3. To quantitatively determine the effect of production of USP/TH-1 upon other features and wells of the Crystal Hot Springs Resource.
4. To obtain data required to estimate reservoir parameters, production potential, and production lifetime.

Noncondensable Gases

Well USP/TH-1 was flowed at a rate of approximately 7 gmp into a 55 gallon separator. The separator was operated in a steady-state mode such that water inlet and outlet flows, separator level, and the noncondensable gas outlet flow rate remained constant. The separator was operated at essentially atmospheric pressure.

The water flow rate from the separator was determined by measuring the time required to fill a calibrated volume. Noncondensable gas flow rates were measured via two techniques--using a rotameter and by filling a tank of known volume. Water and gas discharge temperatures were measured with a mercury thermometer. The apparatus used in testing is schematically depicted in Figure 10.

Using the data obtained via the outlined procedures, the noncondensable gas flashpoint within the wellbore was calculated based upon pressure/ solubility relationships.

A third method was also used to determine the noncondensable gas flashpoint. During artesian flow testing, a downhole pressure gauge was suspended within the well by a wireline. During retraction of the wireline from the well at the conclusion of testing, definite calcium carbonate scale deposition horizons, indicative of the noncondensable gas flashpoint, were observed and recorded.

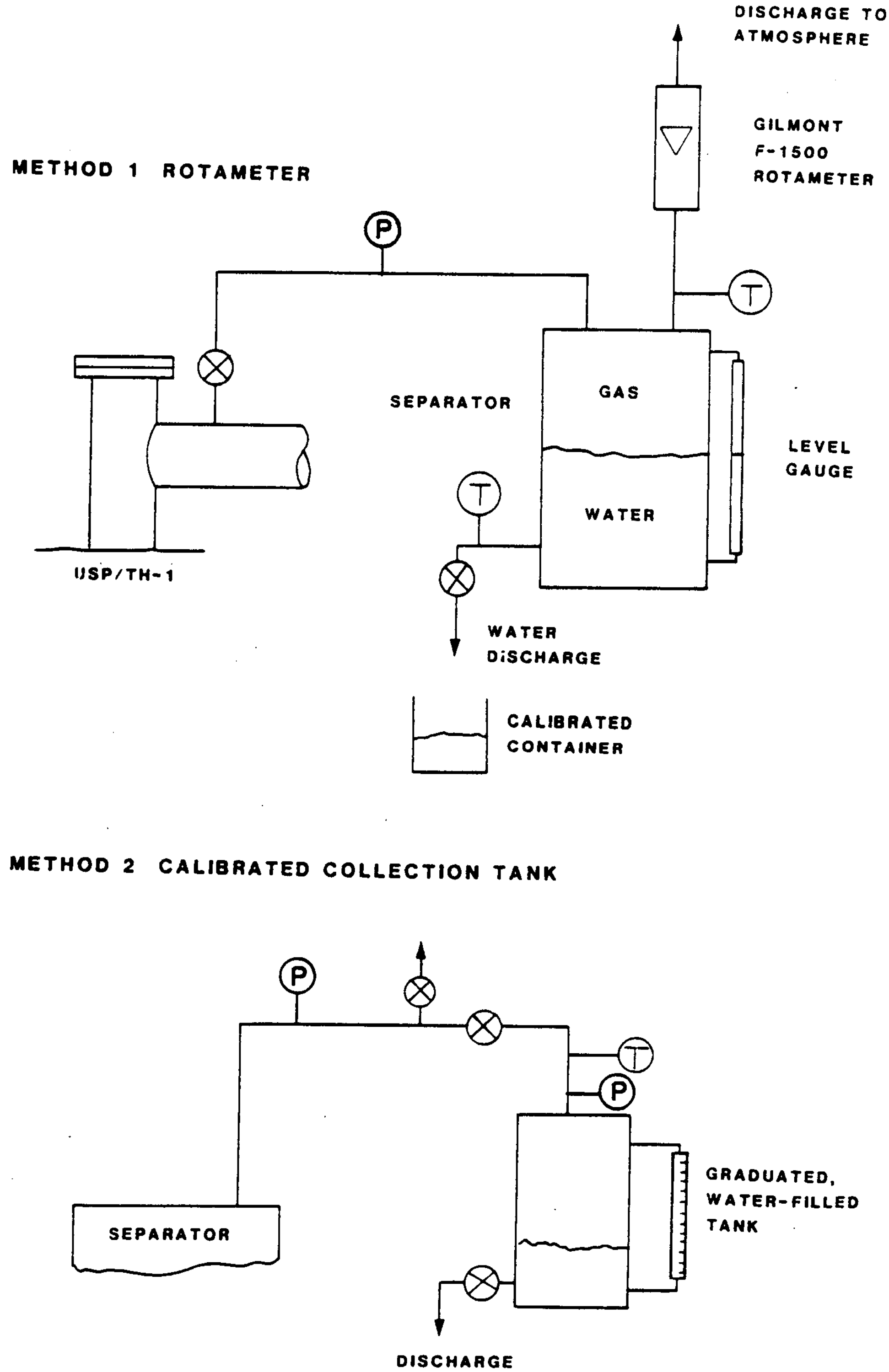


FIGURE 10

APPARATUS FOR MEASURING NON-CONDENSIBLE GAS CONTENT

TABLE V

Noncondensable Gas Data for the Utah Roses

Production Well - Crystal Hot Springs

December 31, 1979

Noncondensable Gases	Percent by Volume
Hydrogen Sulfide As H_2S	4.14
Carbon Monoxide as CO	6.86
Total Hydrocarbon as CH_4	-
Ammonia as NH_3	0.35
Nitrogen Dioxide	26.79
Carbon Dioxide as CO_2	51.09
Sulfur Dioxide as SO_2	6.62
Nitrous Oxide as NOX	4.14

Artesian Flow Testing

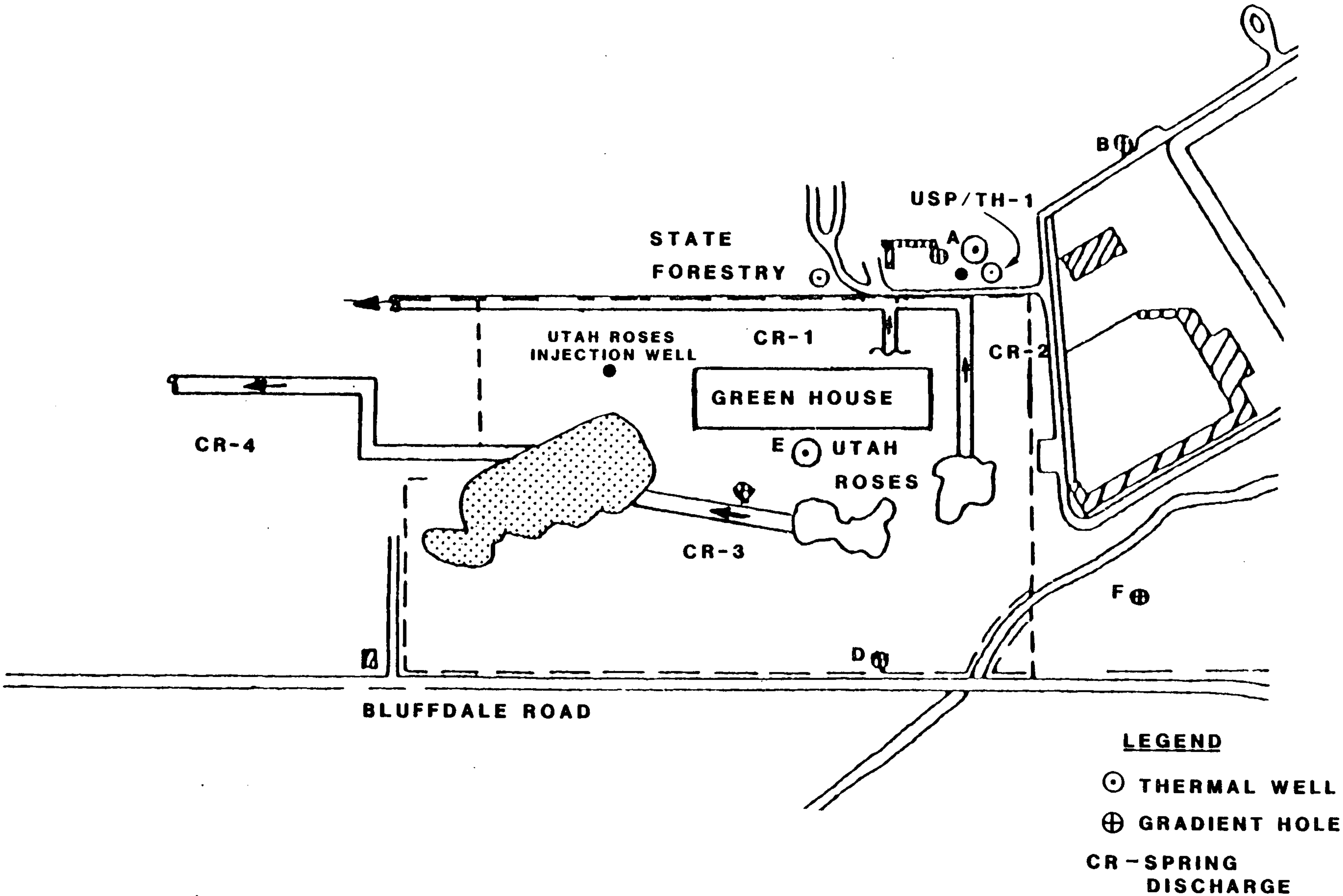
The production characteristics of well USP/TH-1 were determined from a controlled artesian flow test. Testing was conducted over a 72 hour period. For the first 15 hours of testing, the well was flowed at an essentially constant rate of 575 gpm. For the next 33 hours of testing, the well was flowed at a rate of 400 gpm. After 48 hours, the well was shut-in and allowed to recover. Pressure drawdown (during the first 48 hours) and pressure recovery (following shut-in) were monitored regularly during the test. The temperature of the flow from the well was also measured frequently.

In addition to monitoring well USP/TH-1, periodic measurements were made at other wells and springs associated with the Crystal Hot Springs resource. Measurement locations are shown in Figure 11. Pressures (or static water elevations) were monitored in well SF-1 and in Gradient Holes B, D, E, and F. Flow rates from springs CR-2 and CR-3 were also measured. Utah Roses' production rate during the test was also measured.

The configuration of the wellhead apparatus is depicted in Figure 12. Within the vertical run of the well was an 8 inch gate valve. A standard 8 inch tee was situated directly above the valve. An 8 inch diameter by 4 foot long discharge pipe was attached to the branch leg of the tee. Following the 8 inch pipe was a 14 foot section of 6 inch pipe containing a flow measurement device. A six inch gate valve was positioned at the end of the discharge line for flow control.

FIGURE 11

ARTESIAN FLOW TESTING MONITORING STATIONS



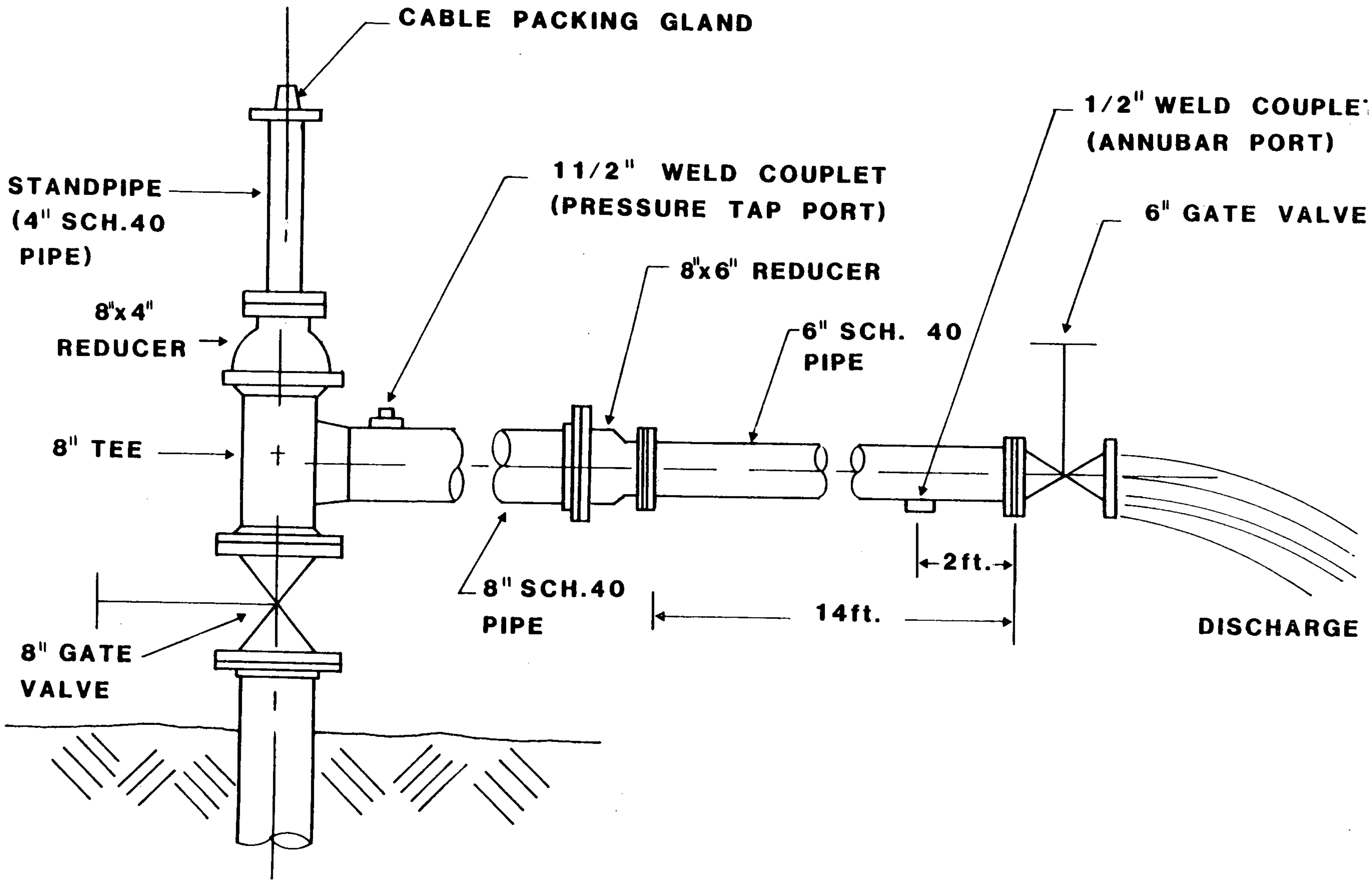


FIGURE 12

WELLHEAD ASSEMBLY WELL USP/TH-1

Access to the well for the downhole pressure probe and cable was provided by a standpipe situated on the run leg of the wellhead tee. A packing was located at the top of the standpipe for sealing of the cable.

During the test formation pressures were measured using a Lynes RES-300 downhole reservoir evaluation system. This system consists of a digital surface recorder, a single conductor cable, and a downhole probe. Downhole pressure measurements were necessitated due to the effect of noncondensable gases upon wellhead pressure measurements. This system was also used to measure downhole temperatures during the test.

To provide redundancy information for pressure measurement, additional pressure data was obtained at the wellhead. A dial pressure gauge and manometers (mercury and water) were plumbed to a sampling port on the 8 inch diameter discharge pipe for this purpose.

Well flow rates were measured by two independent methods. A Dieterich Standard Type 73 Annubar (differential pressure flow sensor) installed in the 6 inch diameter discharge pipe provided one means of flow measurement. Differential pressures generated by this sensor were measured with an air over water U-tube manometer. A standard 9 inch Parshall Flume installed in the discharge channel downstream of the wellhead assembly provided a second means of measuring the well discharge flow.

Wellhead temperatures were measured with a Type K thermocouple which was connected to a digital readout instrument.

Pressure drawdown and recovery in well SF-1 was measured with a dial pressure guage and a mercury manometer. Static water levels in Gradient Holes B, D, E, and F were measured using a conductivity-type depth sensor.

Three inch Parshall Measuring Flumes were previously installed to measure the discharge from Springs CR-2 and CR-3 as a part of the monitoring program. These flumes were used to measure the flow rate of these springs during the test. A 6 inch Parshall Measuring Flume installed within a drainage ditch was used to measure Utah Roses' production rate.

RESERVOIR TEST RESULTS AND CONCLUSIONS

Noncondensable Gases

Using the previously outlined separation technique, noncondensable gas concentrations at wellhead conditions were found to range from 0.08 to 0.22 weight percent. The noncondensable gas was assumed to be primarily carbon dioxide because no odor of hydrogen sulfide was detected during the well test. Using solubility relationships and the above gas concentrations, noncondensable gas flashpoints in the wellbore were calculated to range from 140 feet to 270 feet from the wellhead under hydrostatic wellbore conditions.

In the above results, the lower figures (0.08 weight percent noncondensable gas with corresponding 140 feet flashpoint) were obtained using a volumetric displacement technique. This technique is probably the more reliable of the two methods used in the testing.

Visual inspection of the pressure gauge wireline cable during removal from the well yielded the following:

1. A distinct scale deposit was present on the first 160 feet of cable extracted from the well.
2. The next 60 feet of cable had decreasing amounts of deposition.
3. No deposit was noticeable on the cable beyond the 220 foot mark.

In view of the above results, the noncondensable gas flashpoint within the wellbore should be considered to be at least 220 feet when considering pump setting depth requirements.

Artesian Flow Tests

Analysis of surface and downhole drawdown data from well USP/TH-1, downhole recovery data from well USP/TH-1, and drawdown/recovery data from well SF-1 yielded the following values for important well and reservoir parameters:

1. Permeability = 1570 - 4340 millidarcy
2. Porosity/Compressibility Product = 1.59×10^{-5} psi^{-1}
3. Well Skin Factor = -1.51
4. Reservoir Area = 4.5×10^{6} ft^{2}
5. Impermeable Boundary Location = 730 ft. from well
6. Well/Reservoir Shape Factor 0.101

The above parameters indicate a highly permeable reservoir (similar to that of a fine medium sand) of somewhat limited area. The determined area corresponds closely to that predicted via the gravity modeling work (Murphy and Gwynn, 1979). The well/reservoir shape factor as well as the inferred impermeable boundary location indicate that test well USP/TH-1 is completed within the periphery of the reservoir. This proximity of USP/TH-1 to reservoir boundaries was evidenced by the rapid transition from an infinite-acting to a pseudo-steady-state flow regime observed in the drawdown data.

It should be noted that the above parameters were based upon the actual response of the test and monitor wells during the test. Concurrent with the testing program, Utah Roses was producing at a constant rate of 260 gpm from its well located approximately 1,000 feet from well USP/TH-1. This production could have had a significant effect upon the results obtained. Unfortunately, it was not possible to precisely define this effect.

To rigorously conduct a multiple well test in a developed reservoir such as that at Crystal Hot Springs, it would be necessary to have a record of the influence of the producing well upon the well to be tested prior to conducting the test. Although proposed earlier in the program, funding limitations and difficulties in reaching an agreement with Utah Roses precluded compilation of this record.

Drawdown Characteristics/Production Potential

Based on the determined reservoir parameters, long term production characteristics of well USP/TH-1 were estimated. Estimates of predicted pressure drawdown versus time for several different flow rates are included as Figure 13. As shown in the figure, long term delivery of the well is somewhat limited due to reservoir boundary effect. For a continuous flow rate of 100 gpm, a drawdown of 275 feet of water is predicted over an 8 month heating season. This amount of drawdown is probably near to the limit which would be tolerable due to the current well configuration and due to pump setting considerations. The well should be capable of sustaining short term flows in excess of 100 gpm to meet peak load requirements, however. Further refinement of these predictions can be made after seasonal system flow requirements are determined during preliminary design activities.

Production temperature at the wellhead averaged 179 degrees F during testing with little variation. It is believed that the well will maintain this termperature during long term production.

Again, it must be emphasized that these predictions are based upon the performance of well USP/TH-1 observed during testing (which was affected by Utah Roses' production). Refinements of these predictions should be made after the effect of Utah Roses' production is better established and after future Utah Roses' flow requirements are defined.

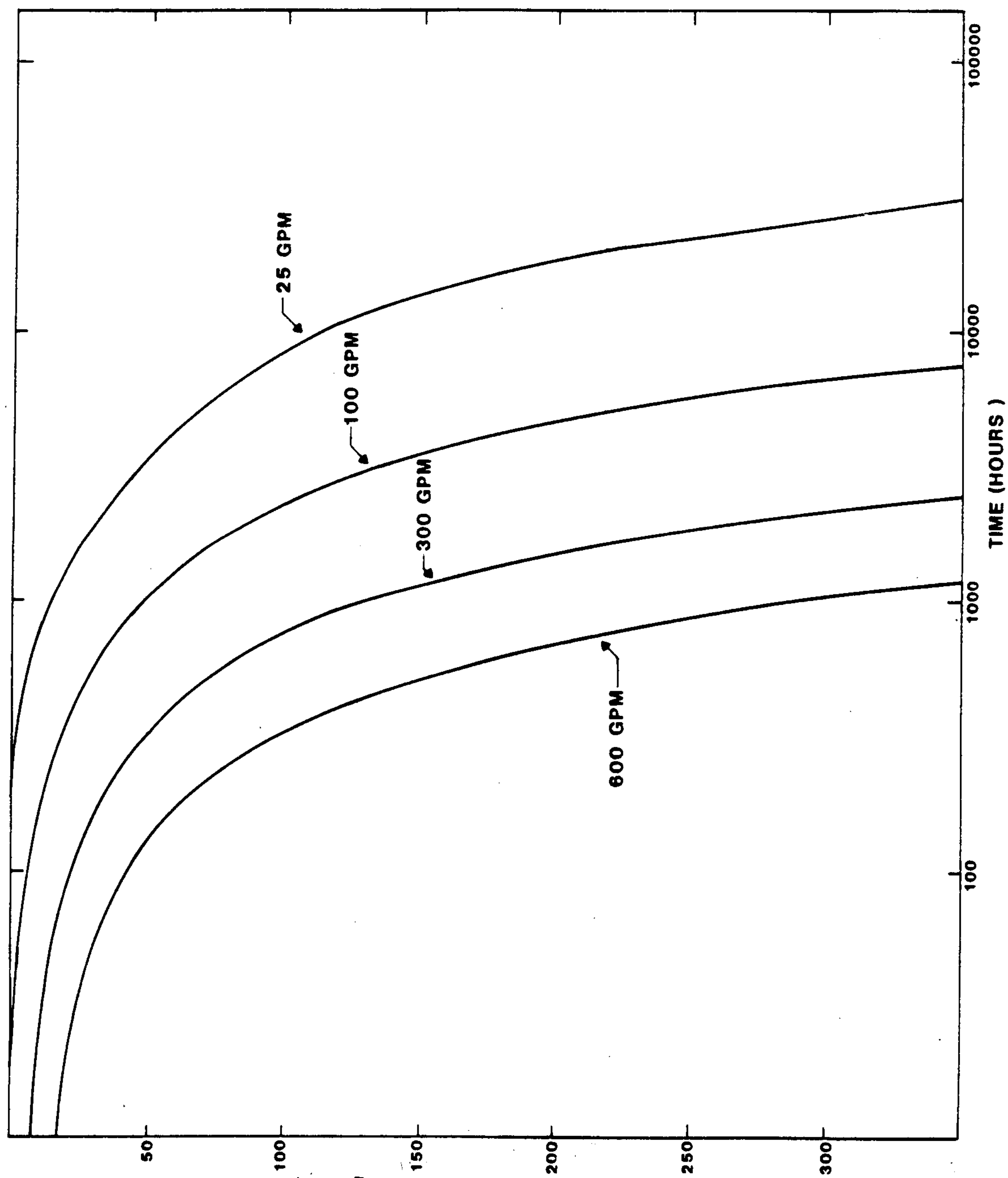


FIGURE 13

PREDICTED LONG-TERM PRESSURE DRAWDOWN CHARACTERISTICS FOR WELL USP/TH-1

In addition, testing was not conducted for a period of time sufficient to assess the effect of system recharge upon the performance of well USP/TH-1. Any significant recharge effects would cause the pressure drawdown in the well to be less than predicted. A long term (30 days) pumped flow test of USP/TH-1 will be carried.

ACTIVITIES IN UPCOMING PERIOD

Due to the limited scope of the test program and short duration of time under which the artesian flow testing was conducted, definitive statements about long-term reservoir productivity cannot be made. Therefore, Terra Tek, Inc., has made the following recommendations in regards to future resource assessment efforts:

1. Due to the limited long term production potential predicted for the prison portion of the resource, drilling of an additional well for production is not warranted at this time.

2. A long term pump test of well USP/TH-1 should be conducted during a period when Utah Roses is not producing its well. The test is necessary to verify the predicted long term drawdown characteristics and to assess any system recharge effects.

3. A test of the Utah Roses Well (or perhaps just careful monitoring) should be conducted to determine the effect of Utah Roses Production upon well USP/TH-1.

4. Seasonal system flow requirements for heating the Minimum Security Building should be established during preliminary system design activites.

5. Current and future production requirements for Utah Roses should be established.

Following completion of the above, the ability of the Crystal Hot Springs resource to supply the anticipated development activities of both the Utah State Prison and Utah Roses, Inc. can be more accurately assessed.

Other activities during the upcoming six months will include:

1. Completion of the investigation of disposal alternatives. (August 1981)

2. Application to the Utah Water Pollution Committee for a construction permit to surface dispose. (September 1981)

3. Completion of the preliminary design and technical/economic feasibility studies for the construction phase of the project by CH_2M Hill. (September 1981)

4. Selection of an Architect/Engineering firm to begin final design efforts.

ACKNOWLEDGEMENTS

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